CHM113 General Chemistry I (Dr. Jen) Key

Chapter 16 Practice Problems

Key Equations

$K_w = [H^+][^-OH] = 1.0 \times 10^{-14}$

$pH = -\log[H^+]$ $\quad pOH = -\log[^-OH]$ $\quad pH + pOH = 14.00$

$K_a = \frac{[H^+][A^-]}{[HA]}$ $\quad K_b = \frac{[BH^+][HO^-]}{[B]}$ $\quad K_a \times K_b = K_w$ $\quad pK_a + pK_b = 14.00$

$pK_a = -\log K_a$ $\quad pK_b = -\log K_b$

1) The dihydrogen phosphate ion, $H_2PO_4^-$, is amphiprotic. In which of the following reactions is the ion serving as a base?

(i) H_3O^+ (aq) + $H_2PO_4^-$ (aq) ⇌ H_3PO_4 (aq) + H_2O (l)
acid → H+ donor; base → H+ acceptor; conj. acid; conj base

(ii) H_3O^+ (aq) + HPO_4^{2-} (aq) ⇌ $H_2PO_4^-$ (aq) + H_2O (l)
acid; base; conj. acid; conj. base

(iii) H_3PO_4 (aq) + HPO_4^{2-} (aq) ⇌ 2 $H_2PO_4^-$ (aq)
acid; base; conj. acid & conj. base

2) For each reaction, predict whether the equilibrium lies to the left or to the right: stronger → weaker

(a) H_2O (l) + HPO_4^{2-} (aq) ⇌ (left) $H_2PO_4^-$ (aq) + ^-OH (aq)
acid; base; conj. acid; conj. base
weaker; weaker; stronger; stronger

(b) NH_4^+ (aq) + ^-OH (aq) ⇌ (right) NH_3 (aq) + H_2O (l)
acid; base; conj. acid; conj. base
stronger; stronger; weaker; weaker

3) A solution at 25 °C has a pOH = 10.53. Which of the following statements is or are true?

(i) The solution is acidic.

(ii) The pH of the solution is 14.00 – 10.53.

(iii) For this solution, $[^-OH] = 10^{-10.53}$ M.

$pH = 14.00 - pOH = 14.00 - 10.53 = 3.46$ (< 7.00) ∴ acidic

$pOH = -\log[OH^-]$

$[OH^-] = 10^{-pOH} = 10^{-10.53}$

4) Order the following solutions from lowest to highest pH: (acidic → basic)

(i) 0.10 M NaClO

Na^+ negligible acid; ClO^- weak base

$ClO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HClO_{(aq)} + {}^-OH_{(aq)}$

basic ∴ ↑ pH

(ii) 0.10 M KBr

K^+ Br^- both negligible ∴ neutral

1 pH

(iii) 0.010 M NH_4ClO_4

NH_4^+ weak acid; ClO_4^- negligible base (b/c conj. base of strong acid HClO$_4$)

∴ ↓ pH

Order: iii < ii < i (low pH → high pH; acidic; neutral; basic)

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Chapter 16 Review (extra)

1) Which one of the following is a **weak** acid?

(a) HNO_3 (b) HI (c) HBr (d) HF (e) $HClO_3$

strong strong strong weak strong

2) Which salt is **not** derived from a strong acid and a strong soluble base?

$Mg(OH)_2$ ≠ from strong base, from HCl ✓ from $Ba(OH)_2$ ✗ from LiOH ✓ from CsOH ✓ from NaOH ✓

(a) $MgCl_2$ (b) $Ba(NO_3)_2$ (c) $LiClO_4$ (d) CsBr (e) NaI → from HI ✓

↳ from HNO_3 ✓ ↳ from $HClO_4$ ✓ ↳ from HBr ✓

3) Which one of the following is a strong electrolyte?

↳ fully dissociates (strong acid & base & soluble salts)

(a) $H_2O(l)$ ✗ (b) KF soluble salt (c) HF ↳ weak acid ∴ partial dissociation ∴ weak electrolyte (d) HNO_2 ↳ weak acid ∴ weak electrolyte (e) $(CH_3)_3N$ ↳ weak base ∴ weak electrolyte

4) In a sample of pure water, only one of the following statements is **always** true at all conditions of temperature and pressure. Which one is always true?

$K_w = 1.0 \times 10^{-14}$ @ 25°C

(a) $[H_3O^+] = 1.0 \times 10^{-7}$ M (b) $[OH^-] = 1.0 \times 10^{-7}$ M (c) pH = 7.0

(d) pOH = 7.0 (e) $[H_3O^+] = [OH^-]$

so a, b, c d are only true @ 25°C

$K_w = [H_3O^+][^-OH]$ ↔ same [] in pure H_2O so

5) If K_w is 2.9×10^{-15} at 10 °C, what is the pH of pure water at 10 °C?

$K_w = [H^+]^2$ so $[H^+] = \sqrt{K_w}$

(a) 6.72 (b) 7.00 (c) 7.27 (d) 7.53 (e) none of these

$[H^+] = \sqrt{2.9 \times 10^{-15}} = 5.39 \times 10^{-8}$

$pH = -\log[H^+] = -\log(5.39 \times 10^{-8}) = 7.27$

$pH = 14.00 - pOH$

6) The pOH of a solution of NaOH is 11.30. What is the $[H^+]$ for this solution?

$= 14.00 - 11.30 = 2.70$

$pH = -\log[H^+]$ so $[H^+] = 10^{-pH} = 10^{-2.70} = 2.0 \times 10^{-3}$ M

(a) 2.0×10^{-3} M (b) 2.5×10^{-3} M (c) 5.0×10^{-12} M (d) 4.0×10^{-12} M

(e) 6.2×10^{-8} M

7) The $[H_3O^+]$ in a 0.050 M solution of $Ba(OH)_2$ is:

$pOH = -\log[^-OH] = -\log(0.10) = 2.0$

$pH = 14.00 - pOH = 14.00 - 1.00 = 13.00$

$Ba(OH)_{2(aq)} \rightarrow Ba^{2+}_{(aq)} + 2\,^-OH_{(aq)}$ so $[^-OH] = 2 \times 0.050\,M = 0.10\,M$

strong base

(a) 1.0×10^{-5} M (b) 5.0×10^{-2} M (c) 1.0×10^{-13} M (d) 5.0×10^{-10} M

(e) 2.0×10^{-5} M

$pH = -\log[H_3O^+]$

$[H_3O^+] = 10^{-pH} = 10^{-13.00} = 1.0 \times 10^{-13}$ M

8) What is the approximate pH of a solution labeled 6×10^{-5} M HBr?

↳ strong acid $HBr_{(aq)} \rightarrow H^+_{(aq)} + Br^-_{(aq)}$ (1:1)

$pH = -\log[H^+] = -\log(6 \times 10^{-5})$

$pH = 4.2$ makes sense ble low pH & strong acid

(a) 4.2 (b) 4.5 (c) 5.8 (d) 9.8 (e) 8.2

9) What is the pH of 500. mL of solution containing 0.0124 grams of $Ca(OH)_2$?

$0.0124\,g\,Ca(OH)_2 \times \frac{mol\,Ca(OH)_2}{74.093\,g\,Ca(OH)_2} \times \frac{2\,mol\,^-OH}{1\,mol\,Ca(OH)_2} \times \frac{1}{500.0\,mL} \times \frac{1\,L}{1000\,mL} = 6.69 \times 10^{-4}\,M\,^-OH$

↳ strong base $Ca(OH)_{2(aq)} \rightarrow Ca^{2+}_{(aq)} + 2\,^-OH_{(aq)}$

plan: $M = \frac{mol\,^-OH}{L}$ → g → mol → mol → M ($Ca(OH)_2$ mole ratio ^-OH ✓)

$pH = 14.00 - pOH = 14.00 - (-\log[^-OH]) = 14.00 - (-\log(6.69 \times 10^{-4})) = 10.83$

(a) 11.04 (b) 9.68 (c) 2.96 (d) 3.17 (e) 10.83

10) The pH of a solution is 4.80. What is the concentration of hydroxide ions in this solution?

$pH = -\log[H^+]$

so $[H^+] = 10^{-pH}$

$[H^+] = 10^{-4.80}$

$[H^+] = 1.6 \times 10^{-5}$ M

$K_w = [H^+][^-OH]$

$[^-OH] = \frac{K_w}{[H^+]} = \frac{1.0 \times 10^{-14}}{(1.6 \times 10^{-5})} = 6.3 \times 10^{-10}$ M ← assumed @ 25°C unless specified otherwise

(a) 4.2×10^{-9} M (b) 1.6×10^{-5} M (c) 3.6×10^{-12} M (d) 6.3×10^{-10} M

(e) 2.0×10^{-8} M

Key

11) Which of the following weak acids ionizes to give the **strongest** conjugate base?

(a) HClO (b) CH_3COOH (c) HF (d) HNO_2 (e) HCN

$HClO \rightleftharpoons H^+ + ClO^-$; $H^+ + CH_3COO^-$; $H^+ + F^-$; $H^+ + NO_2^-$; $H^+ + CN^-$

* anion(-) is on highly EN atom ∴ more stable than C ∴ more favorable forward rxn ∴ strongest acids ∴ weakest acid ∴ smallest K_a in ENSO ∴ strongest conj base

12) The pH of a 0.02 M solution of an unknown weak acid is 3.7. What is the pK_a of this acid? ↳ doesn't specify equilibrium ∴ initial

(a) 5.7 (b) 4.9 (c) 3.2 (d) 2.8 (e) 3.7

Know: $pH = 3.7$ Want: $pK_a = -\log K_a$ $K_a = \frac{[A^-]_{eq}[H^+]_{eq}}{[HA]_{eq}}$

$pH = -\log[H^+]_{eq}$ so

$[H^+]_{eq} = 10^{-pH} = 10^{-3.7} = 2 \times 10^{-4} M$

weak acid

$HA_{(aq)} \rightleftharpoons H^+_{(aq)} + A^-_{(aq)}$

I	0.02	∅	∅
C	-2×10^{-4}	$+2\times10^{-4}$	$+2\times10^{-4}$
E	0.02	2×10^{-4}	2×10^{-4}

* molar ratios are all 1:1:1

$K_a = \frac{[2\times10^{-4}][2\times10^{-4}]}{0.02} = 2\times10^{-6}$

$pK_a = -\log(2\times10^{-6}) = 5.7$